Histopathology of Brown Bullhead (*Ameiurus nebulosus*), Smallmouth Bass (*Micropterus dolomieu*), and Yellow Perch (*Perca flavescens*) in Relation to Polychlorinated Biphenyl (PCB) Contamination in the Hudson River

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ABSTRACT

From the 1940s through 1977, at least 590,000 kg polychlorinated biphenyls (PCBs) were released into the Hudson River from General Electric manufacturing plants in Hudson Falls and Fort Edward, New York, USA. In 1984, the U.S. Environmental Protection Agency designated a nearly 322 km reach as the Hudson River PCBs Superfund Site. Here we describe a Fish Health Assessment study, part of the Natural Resource Damage Assessment (NRDA), evaluating the prevalence of toxicopathic lesions in resident brown bullhead (Ameiurus nebulosus), smallmouth bass (Micropterus dolomieu), and yellow perch (Perca flavescens). In fall 2001, 29–51 fish of each species were collected from two highly contaminated areas below the plants (Thompson Island Pool (TIP) and Stillwater Dam Pool (STW)), an upriver reference area (Feeder Dam Pool (FDP)), and a reference lake, Oneida Lake (ODA). We examined histopathologic lesions and observations associated with contaminant exposure: liver—neoplasms, foci of cellular alteration, bile duct hyperplasia; testes—ovotestis (testicular oocytes), germ cell degeneration, altered developmental stage; ovaries—atresia and altered developmental stage. Lesions associated with PCB exposure were defined as those with significantly greater prevalence and/or severity in TIP and STW compared with ODA and FDP. For brown bullhead and smallmouth bass, no lesions or changes in gonadal development met those criteria. In yellow perch, ovarian atresia was the only lesion associated with PCB exposure. Prevalence was 53% in FDP, 75% in ODA, and 100% in both STW and TIP; severity increased from mostly minimal to mild-moderate. Because of the high prevalence of atresia in reference collections, it is likely that factors other than PCBs are also involved. As part of a post–dredging monitoring plan, we recommend assessing gonad structure and function in yellow perch collected at the time of spawning in locations with a range of PCB contamination. The paper is in press in Science of the Total Environment (copies below).

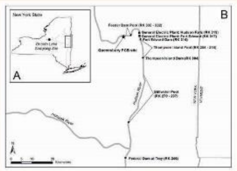

Fig. 1. Map of New York State showing fish collection areas and Hudson River PCB sources. RK: river kilometer from tip of Manhattan (RK 0). A) overall map of New York State; B) Hudson River locations: Feeder Dam Pool (FDP); Thompson Island Pool (TIP), and Stillwater Pool (STW).

INTRODUCTION

- U.S Environmental Protection Agency (EPA) estimated that from 1940s through 1977,at least 590,000 kg of polychlorinated biphenyls (PCBs) released into Hudson River from General Electric (GE) capacitor manufacturing plants in Hudson Falls (River Kilometer (RK) 319) and Fort Edward, NY, USA (RK 317; Fig. 1).

- Natural Resource Damage Assessment (NRDA) is the process of collecting, compiling, and analyzing information, statistics, or data through prescribed methodologies to determine damages for injuries to natural resources from the release of a hazardous substance or discharge of oil. The goal of NRDA is to restore injured natural resources. The Hudson River NRDA is being conducted by the Hudson River Natural Resource Trustees: the National Oceanic and Atmospheric Administration (NOAA), the US Department of the Interior (DOI) and the New York State Department of Environmental Conservation (NYSDEC).

- HRNRT are conducting a NRDA to identify the extent of natural resource injuries, methods for restoration, and the type and amount of restoration required.

- In fall 2001 a Fish Health Assessment study (HRNRT 2001) compared prevalence of toxicopathic lesions in fish from two Hudson River areas highly contaminated with PCBs with those from two reference areas. Studied brown bullhead (Ameiurus nebulosus), smallmouth bass (Micropterus dolomieu), yellow perch (*Perca flavescens*).

- Our goal is to analyze the Fish Health Assessment results to determine if the prevalence of histopathologic lesions or altered gonadal development is associated with PCB exposure.

METHODS

Field work

- Electroshocking and trap netting from four areas (Fig. 1)

  1. Feeder Dam Pool (FDP, ~ RK 330) formed by the Feeder Dam, Glen Falls, NY above the plants; has been used as a reference location for many studies of the more severe contamination below GE plants
  2. Thompson Island Pool (TIP) from Fort Edward (RK 314) to the Thompson Island Dam (RK 304), downriver sampling area closest to GE plants
  3. Stillwater Pool (STW) area, RK 292 to RK 270, above the Stillwater Dam, a highly contaminated downriver area
  4. Oneida Lake (ODA) offsitereference area -- target species are resident, no consumption advisories

- Little fish movement between Hudson River areas which are separated by dams

- >200 mm length, sample size: 50 per assessment area (STW and TIP), 30 in each reference area (FDP and ODA)

Pathology

- Standard necropsy and tissue processing with hematoxylin and eosin

- Lesions in liver and gonad and changes in gonadal development that have been linked with contaminant exposure based on NOAA studies and Myers (unpublished data)

- Liver: all neoplasms, foci of cellular alteration (FCA; likely pre-neoplastic lesions), bile duct hyperplasia (BDH), intrahepatic duct hyperplasia (IDH)

- Testes: germ cell degeneration, seminoma, testicular oocytes, and differences in stage (i.e., altered development)

- Ovaries: prevalence and severity of oocyte atresia (degeneration and resorption of oocytes) and differences in stages of ovarian development

Data analysis

- Used logistic regression to account for possible effects of covariates (e.g, age, length, sex) on lesion prevalence and severity (Pinkney et al. 2014).

- Since no tissue residue data were collected, we used NYSDEC fish tissue data from collection areas circa 2001 as a surrogate data set to rank PCB contamination by location for each species (Fig. 2).

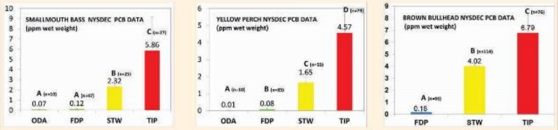

Fig 2. Summary of NYSDEC fish tissue data used for ranking locations. Groups with different capital letters are significantly different at p<0.05 (mixed one factor ANOVA and Tukey's test).

- Test for PCB associated lesions: significant differences between locations such that there is greater prevalence in contaminated (STW, TIP) vs. reference (FDP, ODA) areas

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RESULTS AND DISCUSSION

Brown bullhead: FINDINGS

Liver: No statistically significant differences in prevalence of any lesions
Gonads: No changes in lesion prevalence or severity or gonadal development consistent with PCB exposure

Smallmouth bass (Micropterus dolomieu) FINDINGS

Liver: No significant differences in prevalence of any lesions
Gonads: Differences in male germ cell degeneration statistically significant; not consistent with PCB exposure (FDP=STW=TIP)
Ovotestis prevalence high in all four collections, ranging from 55.5% in ODA to 100% prevalence in both FDP and STW. (no evidence of PCB association)

Yellow perch FINDINGS

Liver: No statistically significant differences in prevalence of any lesions

Gonads: only lesion that may be PCB-related was the prevalence and severity of oocyte atresia (Figs. 3, 4). Two most PCB-contaminated areas (TIP -- 100%, STW -- 100%) significantly greater than the two reference areas (FDP -- 53% and ODA — 75%). Strength of association weak because of high prevalence at FDP and ODA. Sampled 8 months before spawning, difficult to determine to what degree atresia would affect number and quality of eggs.

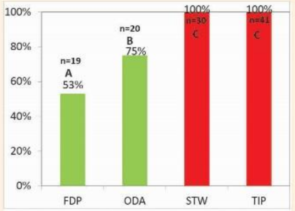
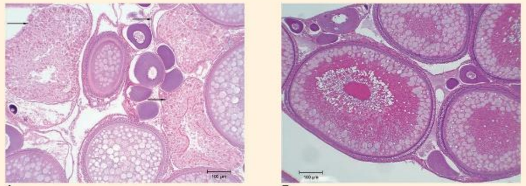


Fig.3 Prevalence of oocyte atresia in yellow perch from different locations based on logistic regression; groups with different letters are significantly different at p<0.05.

Logistic regression results. Only lesions with statistically significant differences are listed. Groups with different letters are significantly different at p<0.05.

YELLOW PERCH				
Lesion	**Covariate**	**p**	**Groupings: smallest to largest**	**Comments**
Gonad stage (Female)	Age	<0.001	TIP, ODA: (A) (less developed); STW, FDP: (B) (more developed)	Not consistent with PCB exposure; ref. and contam. groups not different (ODA=TIP)
Atresia prevalence and severity	None	<0.001	FDP 53% (A), ODA 75% (A), STW 100% (B), TIP 100% (B) (Fig. 3, 4)	Consistent with PCB exposure but high prevalence in reference
Gonad stage (Male)	None	0.048	ODA (A), TIP (A,B), STW (B,C), FDP (C)	Not consistent with PCB exposure; ref. and contam. groups not different (ODA=TIP)
Germ cell degeneration	None	<0.001	FDP (A), STW (A,B), TIP (A,B), ODA (B)	Not consistent with PCB exposure; ref. and contam. groups not different (FDP=STW=TIP)



A B

Fig. 4. Photomicrographs of yellow perch ovaries showing atresia (A) and normal tissue (B); all with hematoxylin and eosin staining.

A. Section of a Stage 1 ovary from a yellow perch from Thompson Island Pool (YP312), illustrating later stages of ovarian atresia in early vitellogenic oocytes (arrows). Atretic oocytes at the right contain remnants of the zona radiata/chorion and phagocytosed contents of the spherical cortical alveoli and yolk granules within the granulosa/thecal cells which have migrated into the atretic oocyte. Also visible are highly basophilic secondary oocytes and normal early vitellogenic oocytes. Scale bar = 100 um.

B. Section of a Stage 1 ovary from a yellow perch from Feeder Dam Pool (YP452), demonstrating normal early vitellogenic oocytes unaffected by ovarian atresia. Note the thick, intact zona radiata/chorion, thin perifollicular layer/complex, intact central nucleus, and intact, spherical cortical alveoli and yolk vesicles in the normal early vitellogenic oocytes. Also present are normal secondary/previtellogenic oocytes. Scale bar = 100 um.

CONCLUSIONS

- Although the Superfund-mandated dredging is complete, areas within the river still contain PCB contaminated sediments (Field and Rosman 2016). A post-dredging monitoring plan should focus on yellow perch reproductive effects in areas with varying degrees of PCB contamination.

- Bullhead and bass: No evidence of PCB-associated lesions or altered gonad development.

- Yellow perch: statistically significant differences in prevalence and severity of oocyte atresia that followed a pattern consistent with PCB exposure. Strength of association is weak due to high prevalence in reference areas.

- **As part of a post-dredging monitoring plan, we recommend conducting a yellow perch reproduction study in Hudson spawning areas with varying sediment PCB concentrations. Conduct during the spawn, the most relevant time for measuring reproductive success.**

- **Endpoints of proposed study: histopathology of testes and ovaries; sperm motility and volume; PCB and organochlorine pesticides in ovaries, testes, muscle, and liver.**

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